



8th International Symposium
on the Conservation of Monuments
in the Mediterranean Basin

**Monument Damage Hazards
& Rehabilitation Technologies**



UNDER THE AUSPICES OF I.G.C.M.M.

Proceedings

Volume I

31 May
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Technical Chamber of Greece

**8th INTERNATIONAL SYMPOSIUM
ON THE CONSERVATION OF MONUMENTS
IN THE MEDITERRANEAN BASIN**

May 31 - June 2, 2010 - Patras, Greece



**MONUMENTS DAMAGE HAZARDS AND
REHABILITATION TECHNOLOGIES**

PROCEEDINGS

VOLUME I

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- University of Patras
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Presentation

These volumes contain the papers presented at the 8th International Symposium on the Conservation of Monuments in the Mediterranean Basin held in Patras, Greece, from 31 May until 2 June, 2010. The Symposium, following previous symposia in Bari (1989), Geneva (1991), Venice (1994), Rhodes (1997), Seville (2000), Lisbon (2004), and Orléans (2007), was organized by the National Technical University of Athens (NTUA, School of Chemical Engineering, Materials Science and Engineering Section), the University of Patras and the Technical Chamber of Western Greece.

This International Symposium, provided a forum for scientists, technicians and experts, in the area of conservation and restoration of monuments, to present their work and exchange ideas and experiences. During the Patras 2010 Symposium, new opportunities were presented and deepened the existing knowledge base regarding the problems of cultural heritage.

The theme chosen for this Symposium, “Monument Damage Hazards and Rehabilitation Technologies”, refers to the natural and anthropogenic hazards on monuments, as well as to the technologies used for damage rehabilitation. A large array of topics enabled scientists to discuss and share the main problems they encounter in their monument projects in the Mediterranean Basin. Thus, the Symposium addressed restoration engineers, architects, geologists, restorers and conservators of stone artifacts and other specialists in the decay and restoration of monuments, as well as archaeologists, art historians and scientists in the fields of physics, chemistry and biology. Furthermore, the Symposium aimed at intriguing the interest of both cultural institutions involved in heritage management and manufacturers of building treatment products.

In this Symposium more than 350 authors, attendees, exhibitors and sponsors came from Belgium, Canada, Cyprus, Finland, France, Germany, the Great Britain, Greece, India, Iran, Italy, the Netherlands, Portugal, Serbia, Spain, Tunisia, Turkey, etc. to participate.

All the papers were critically reviewed by the members of the Scientific Committee, to whom I would like to attribute my deepest gratitude for all their essential effort and co-operation in this very important aspect of the

Symposium. The papers in these volumes are arranged according to the topics and alphabetically ordered.

I would also like to express my special thanks to Dr. Dimitrios Kouis (Computer Engineer), Dr. Nico Avdelidis (Materials Engineer), Eleni Cheilakou (Chemical Engineer), Panayiotis Papandreopoulos (Chemical Engineer) and Panagiotis Theodorakeas (Chemical Engineer) for their crucial contribution to the preparation and edition of these volumes.

Many thanks should be given to the Organizing Committee members for organizing the sessions and for their excellent work, as well as the secretariat, Mrs Kanella Pouli and Mrs Mary Sypsa, whose contribution is considered of utmost importance for the success of the Symposium. To them great thanks are attributed by the IGCM.

Last, but not least, I would like to express my thankfulness to all sponsors for their financial support.

*Professor Maria Koui
Coordinator of the Organizing Committee*

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STATIC REQUIREMENT AND TYPE'S COMPLEXITY IN THE DIAGNOSTICS PHASE

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Keywords: Structural complexity, static requirements, refurbishment interventions, diagnosis phase, conservation

Abstract

The preservation of an historical building, whatever its architectural and/or artistic value, is more appropriate as it is deeper the building knowledge, its development, its materials and constructive techniques. So the preliminary phase of a restoration intervention is the data acquisition, the direct characteristics and conditions recognition of the building and the survey of significant alterations. The reasons that cause these modifications, in great number of cases, are not respectful of the building static efficiency, so its static requirement could be weakened. In fact, a very high percentage of building damages is attributable to these modifications are not always sufficiently respectful of a structural balances consolidated over time. The study focuses on the analysis of the restoration intervention on two trilobate pillars that separate the central space from the presbytery in the Cathedral of Matera,

a little city in the southern part of Italy. Through the use of sonic tests - carried out despite the complexity of the shape of a building structural and constructive elements that characterizes these pillars - it was possible to show the effectiveness of the implemented intervention, highlighting its critical points and its weaknesses. The research aims to show how - despite the type complexity of some structural elements of a building - becomes essential an appropriate building knowledge to realize interventions that are able to operate a correct restoration interventions of a building and, at the same time, that it is respectful of its type and material peculiarities.

Introduction

The preservation of an historical building, whatever its architectural and/or artistic value, is more appropriate as it is deeper the building knowledge, its development, its materials and constructive techniques.

In fact, the protection and conservation of monumental heritage represent varied and sometimes even alarming aspects; however, they help us to identify the commonly called "architectural emergency". This is essentially related to the size and the great number of cases to resolve and - together - to the limited availability of usable resources and experiences.

So, it's necessary to optimize in a better way the just limited financial and temporal resources, giving to our monuments the respect that compete themselves. Faced with a degraded monument, the renovation designer can meet three main questions: "if" to perform a restoration, "where" to perform a restoration and "how" to perform a restoration.

To these questions it is possible to add another one that regarding the economic aspect: "when" to perform a restoration intervention.

In order to respond adequately to these questions, it is necessary to advance "stepbystep", through easily defined procedures, as the degradation identification, the causes determination, the assessment of residual safety and, finally, through the suitable intervention choice and the definition of its executive method. So the preliminary action is the research of all information about the monuments; these informations are required to describe the structure and all the transformations that it has suffered; in this situation, it becomes essential the history knowledge of the building, from its construction until the last modification that it has undergone.

In the first phase of data acquisition, the direct recognition of the building characteristics and the survey of the checked alteration, should be complemented by research of design documentation and of events that have affected the structure during all its life cycle.

Shape's Complexity and Static Balance

The structural and static complexity of the historical building represent the more important characteristics of each monuments.

In fact, in the last years, the necessity to operate interventions of masonry structural reinforcement has become increasingly urgent, stimulating both by the objective requirements related to increased degradation of the monumental buildings and by a greater interest towards conservation theory.

The restoration criteria, in fact, impose severe restrictions on the possibility to realize a different intervention types but - at the same time - stimulate the choice of the suitable solutions.

Naturally, these solutions will sought in changes to realize to the main parameters that constitute the mechanical part of the structure (i.e. the geometry, material and loads).

In fact, changes, modifications, partial demolition and reconstruction are quite frequent in a building history, especially in a monumental building. A lot of monuments, in fact, have modified its shape and its structural and functional organization in its life cycle, realizing - for example - of superelevation or addition part of construction, modifying the static distribution of the force, etc.; a very high percentage of building damages is attributable to these modifications are not always sufficiently respectful of a structural balances consolidated over the time.

These changes led new structural stresses - not always proportionately allocated over the building structure - and very often they led a new shape and aesthetical characteristics.

Thus, the geometry changes are surely the most effective (i.e. the increase of stiffness obtained with the increase of resistant section or by adding a constraint). The criterion for an intervention on the geometry was almost abandoned, although structurally good; the practice of complete replacement of degraded

elements with other more or less “similar” to the original is realized very often, while frequently are offered - in parallel to existing structures - structures that are able to bear the load of the structure, in case of triggering the collapse.

It is considered, therefore, that the elaboration of a proposed consolidation intervention is essential to achieve different objectives that ensure the maximization of the monument respect.

These objectives are:

1. to allow maximum persistence of the original material, limiting at minimum the transformations (demolition, replacement, etc.);
2. to recognize the variable “time” as a positive sign that are able to add value to the building, which must be understood as a “palimpsest” on which are layered different elements;
3. to use objective knowledge that are closely related to the building or specific pathological situation;
4. to make decisions on the basis of technical assessments, supported by an in-depth knowledge and never based on historical, critical or aesthetic judgments;
5. to realize recognizable and reversible interventions, in order to make possible in the time control, monitoring, additional maintenance (i.e. the introduction of new technologies or systems more effectively);
6. to establish a correct maintenance program over time, not aimed at any replacements intervention at predetermined intervals, but based on observation of the phenomena, in order to prevent possible dangerous situations and slow down the aging process of the building.

The Case Study

This research focus upon the Cathedral of Matera - a little city in the southern part of Italy (Figure 1), a massive architectural structure, built at the end of the XIII century.



Figure 1: The Matera Cathedral

In Apulian Romanesque style, it keeps its formal and architectonic connotations almost unchanged outside, even though some interventions have substantially changed the inside style. It does not show any plain deterioration signs of its static structure, but it is plain a pathology outside.

The study focuses on the analysis of the restoration intervention on two trilobate pillars (Figure 2) that separate the central space from the presbytery.

Through the use of sonic tests - carried out despite the complexity of the shape of a building structural and constructive elements that characterizes these pillars - it is possible to show the effectiveness of the implemented intervention, highlighting its critical points and its weaknesses.

In fact, with the sonic tests are measured and analyzed the characteristics of propagation of elastic waves inside the walls with the aim to understand the homogeneity of the structure, the changes of material properties caused by degradation, the structural defects - such as cavities or cracks - and the magnitude of the resistance of materials.

This test is carried out by measuring the time and speed of the wave that passes through the wall, a mechanical impulse generated by a transmitter and picked up by



Figure 2: The trilobate pillars

a receiver.

The speed of an elastic waves in a homogeneous, isotropic and perfectly elastic, is linked to the dynamic elastic modulus E_d , by the following relation:

$$\text{in which: } E_d = v^2 \cdot d \cdot \frac{(1+\nu)(1-2\nu)}{(1-\nu)}$$

E_d = dynamic modulus in Pa

v = speed of the wave in ms⁻¹

ν = Poisson modulus

d = density of the elements in kgm⁻³

The elastic wave loses energy in his propagate, and this is due to a decrease in the intensity related to the propagation law of the spherical type, while another decrease is the interface between the gap, where the energy is partly reflected and partly refracted.

High speed - closely proportional to the elasticity modulus and to the strength of the element - and short term indicate a compact structure (i.e. single body masonry or multiple body well connected), while discontinuities, fractures, porous materials are considerably lower speed and consequently increases time.

The test was performed on the above said columns, identifying different directions (Figure 3 and Figure 4) - at different heights - in order to cover the largest part of the surface; these directions would also consider the different materials connections, related to the particular shape of the pillars. Certainly this complexity became an important element to evaluate in order to operate a correct and precise evaluation of the investigations project.

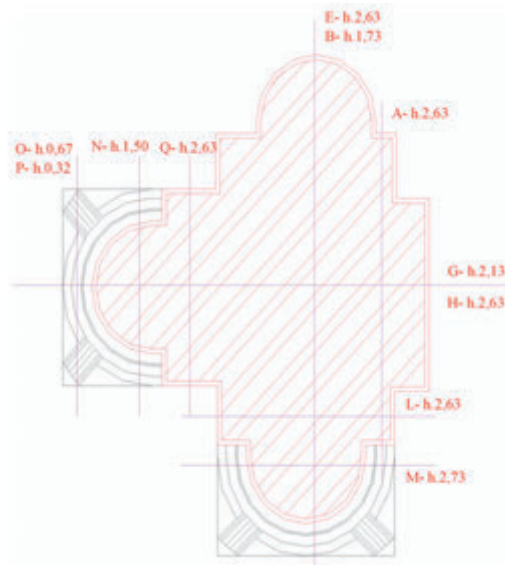


Figure 3: Sonic directions of investigations carried out on the left trilobate pillar

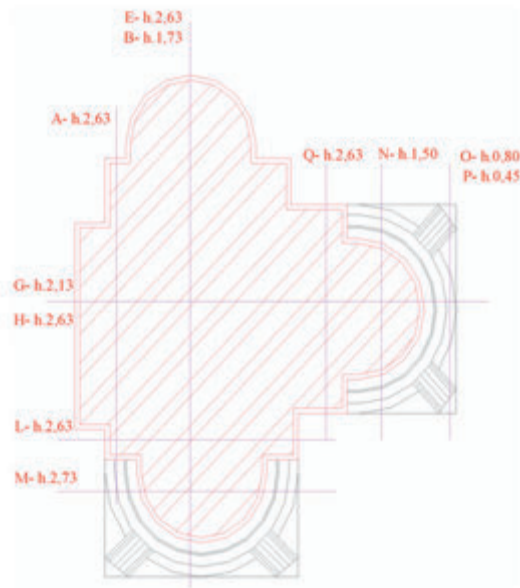


Figure 4: Sonic directions of investigations carried out on the right trilobate pillar

Table 1: Sonic tests results on the left trilobate pillar

A ₁			B ₁			C ₁			D ₁		
s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)
1.57	942	1886,902	2.37	1315	1763,13				2.37	1374	1768,393
	919			1321						1285	
	944			1317						1295	
	921			1352						1281	
	947			1331						1345	
	933			1346						1332	
	929			1343						1340	
	909			1348						1376	
	922			1372						1340	
	941			1355						1363	
	953			1362						1361	
919	1369	1362									
G ₁			H ₁			L ₁					
s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)			
		1598,837	1.87	1199	1823,145	0.95	613	1434,395			
				1212			634				
				1172			628				
				1116			691				
				1147			679				
				1141			644				
				1173			661				
				1147			692				
				1176			666				
				1161			676				
				1192			692				
	1198	690									
M ₁			N ₁			O ₁			P ₁		
s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)	s(m)	t(us)	V(m/s)
0.61	371	1474,142	0.96	448	1494,075	0.96	341	2785,839	0.96	391	2442,748
	437			438			393				
	402			415			399				
	399			429			399				
	412			409			381				
	432			431			343				
	364			353			351				
	391			374			342				
	472			354			350				
	408			348			344				
	435			354			338				
482	379	343									

usually characterize those walls not strongly degraded and presence of voids.

From the observation of results, it is possible to note that lower values are not recorded along the longest paths - such as those linking the two semi-columns or the semi-column with the pilaster - but along the shortest paths within the elliptical shape. This leads us to assume a more widespread damage, also visible on the surface of the pillars.

While, the investigations on the right pillar (Tab. 2) highlight of values between 1450 m/s and 1850 m/s at different levels and in the range 1.50-2.73, which usually characterize those walls not strongly degraded and presence of voids. Even the pillar right, by the observation of partial results show that higher values are recorded along the longer trajectories (as above said), the lowest (about 1400 m/s) along the shortest paths within the elliptical shape. This leads us to do the same considerations of the left pillar.

Table 2: Sonic tests results on the right trilobate pillar

Ad			Bd			Cd			Dd			Ed		
slm	t(us)	V(m/s)	slm	t(us)	V(m/s)	slm	t(us)	V(m/s)	slm	t(us)	V(m/s)	slm	t(us)	V(m/s)
1.49	886	1094.337	2.31	1572	1644.713	2.31	#DIV/0!	2.31	#DIV/0!	2.31	1828.4	1289		1287
	871			1356								1287		
	855			1301								1257		
	870			1424								1309		
	890			1356								1249		
	848			1434								1243		
	924			1427								1079		
	863			1415								1261		
	883			1423								1249		
	870			1427								1271		
	804			1333								1284		
922	1390	1292												
Fd			Gd			Hd			Id			Ld		
slm	t(us)	V(m/s)	slm	t(us)	V(m/s)	slm	t(us)	V(m/s)	slm	t(us)	V(m/s)	slm	t(us)	V(m/s)
1	#DIV/0!	1.81	1082	1750.822	1.81	1883.259	1	#DIV/0!	1	1477.541	820		864	
			1002								859			
			1043								870			
			1046								996			
			1011								937			
			1011								990			
			1005								945			
			1005								947			
			999								990			
			1037								983			
			1096								996			
1116	967													
Md			Nd			Od			Pd			Qd		
slm	t(us)	V(m/s)	slm	t(us)	V(m/s)	slm	t(us)	V(m/s)	slm	t(us)	V(m/s)	slm	t(us)	V(m/s)
0.67	450	1450.059	0.66	444	1440.23	0.68	394	2401.372	0.68	2184.789	9.83	474		474
	474			501										
	496			440										
	461			416										
	411			416										
	436			408										
	455			432										
	496			415										
	450			410										
	452			418										



Figure 5: Damage visible on the surface of the pillars

Sonic tests were carried out also on the stone base of the pillars using the same investigation test. The measured values are greater than 2000 m/s that indicates a good state of preservation.

The research - applied on the above described pillars - is on going also for the other structural elements of the Matera Cathedral in order to provide a complete knowledge of the monument and to develop a suitable restoration intervention.

Conclusions

The research aims to show how - despite the type complexity of some structural elements of a building - becomes essential an appropriate building knowledge to realize interventions that are able to operate a correct restoration interventions of a building and, at the same time, that it is respectful of its type and material peculiarities.

The study aims to realize an applicative methodology more respectful of the monumental heritage, in order to avoid a simple acritical transposition of the calculation models in the recovery interventions.

This research can also contribute to increment the typology of the tests to carry out on the masonry; in fact, in relation to all the problems of tests and investigations (first of all the geometrical complexity), it is not necessary to have only one kind of survey, but an organic plan that consider in particular way the shape and the morphology of the investigated element, in order to have a more possible complete cognitive frame. Only in this way it is possible to interpret the real phenomena and give the necessary parameters to realize a correct intervention.

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